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YUCCA MOUNTAIN - SUPPLEMENTAL RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION - SAFETY EVALUATION REPORT, VOLUME 3 POSTCLOSURE CHAPTER 2.2.1.3.5, 1ST SET - CLIMATE AND INFILTRATION (DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTION 2.3.1) AND POSTCLOSURE CHAPTER 2.2.1.3.6 - FLOW PATHS IN THE UNSATURATED ZONE, SET 1 (DEPARTMENT OF ENERGY'S SAFETY ANALYSIS REPORT SECTIONS 2.3.2 AND 2.3.3)

Reference 1: Ltr, Sulima to Williams, dtd 04/29/09, "Yucca Mountain -Request for Additional Information - Safety Evaluation Report, Volume 3 - Postclosure Chapter 2.2.1.3.6 - Flow Paths in the Unsaturated Zone, Set 1 (Department of Energy's Safety Analysis Report Sections 2.3.2 and 2.3.3)"

Reference 2: Ltr, Sulima to Williams, dtd 5/27/2009, "Yucca Mountain - Request for Additional Information - Volume 3 - Postclosure Chapter 2.2.1.3.5, 1st Set - Climate and Infiltration (Department of Energy's Safety Analysis Report Section 2.3.1)"

Reference 3: Ltr, Williams to Sulima, dtd 6/10/2009, "Yucca Mountain - Supplemental Response to Request for Additional Information - Safety Evaluation Report, Volume 3 - Postclosure Chapter 2.2.1.3.6 - Flow Paths in the Unsaturated Zone, Set 1 (Department of Energy's Safety Analysis Report Sections 2.3.2 and 2.3.3)"

Reference 4: Ltr, Williams to Sulima, dtd 6/24/2009, "Yucca Mountain - Request for Additional Information - Volume 3 - Postclosure Chapter 2.2.1.3.5, 1st Set - Climate and Infiltration (Department of Energy's Safety Analysis Report Section 2.3.1)"

Reference 5: Ltr, Williams to Sulima, dtd 7/20/2009, "Yucca Mountain - Request for Additional Information - Safety Evaluation Report, Volume 3 - Postclosure Chapter 2.2.1.3.6, Set 2 - Flow Paths in the Unsaturated Zone - (Department of Energy's Safety Analysis Report Sections 2.3.2, 2.3.3, and 2.3.5)"

The purpose of this letter is to resubmit the U.S. Department of Energy's response to the Request for Additional Information (RAI) Number 5 identified in reference 1 above (RAI 3.2.2.1.3.6-005) and the response to RAI Number 2 identified in reference 2 above (RAI 3.2.2.1.3.5-002). This resubmittal corrects the response to RAI 3.2.2.1.3.6-005 provided by reference 3 above and the response to RAI 3.2.2.1.3.5-002 provided by reference 4 above.

The response to RAI 3.2.2.1.3.6-005 included in Tables 1 and 3 the values of net infiltration flux over the repository footprint for the unsaturated zone model. Subsequent to the submittal, a mistake was found in infiltration flow rates associated with two of the 532 repository columns used in the development of the spatial average infiltration flux values presented in these tables. The corrected values result in a change in the average infiltration flux of approximately 0.5% for all present-day, monsoon, and glacial-transition climate states (i.e. 10th, 30th, 50th and 90th infiltration percentiles). Mean infiltration fluxes averaged over climate state uncertainty for the repository footprint are similarly affected. Although most of the tabulated values identified above are impacted within the level of precision presented in Tables 1 and 3, because the magnitude of the effect is small, it does not change any of the response text, discussion, or conclusions.

The average net infiltration flux over the repository footprint presented in the response to RAI 3.2.2.1.3.6-005 was also reproduced in the response to RAI 3.2.2.1.3.5-002 in Tables 2 and 3. The resubmitted response to RAI 3.2.2.1.3.5-002 includes a correction to these two tables. The corrections do not affect any of the response text, discussion, or conclusions.

For completeness, the updated response to RAI 3.2.2.1.3.6-005 also includes a corrected Table 4, which was provided to the NRC by reference 5 above, as Attachment 1 to the response to RAI 3.2.2.1.3.6-2-010.

The DOE references cited in the resubmitted RAI responses have previously been provided to the NRC.

There are no commitments in the enclosed resubmitted responses. If you have any questions regarding this letter, please contact me at (202) 586-9620, or by email to jeff.williams@rw.doe.gov.

Linda J. Desell
for

Jeffrey R. Williams, Supervisor
Licensing Interactions Branch
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Office of Technical Management

OTM: CJM-0260

Enclosures (2):

1. Corrected Response to RAI Volume 3, Chapter 2.2.1.3.6, Set 1, Number 5
2. Corrected Response to RAI Volume 3, Chapter 2.2.1.3.5, Set 1, Number 2

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RAI Volume 3, Chapter 2.2.1.3.6, First Set, Number 5, Supplemental:

> Explain how the magnitude and timing of seepage is related to percolation, net infiltration, and precipitation over the repository footprint. To support this explanation, provide a summary table consistent with TSPA-LA results that contains (i) precipitation, (ii) net infiltration (using weights from SNL, 2008), (iii) net infiltration (using GLUE-derived weights), (iv) percolation at repository horizon, and (v) seepage all averaged over the same domain (i.e., repository). The summary values for seepage also should include flux values for percolation subregion and seeping environment in the percolation subregion, and seepage fraction. Consider the nominal and seismic ground motion cases, and the glacial transition and post-10,000-yr climates (percolation and seepage only). This information is needed to verify compliance with 10 CFR 63.114(b).
>
> **Basis:** It is difficult to extract from the SAR a consistent set of values to use in a comparison of flux values on and through the mountain because of the different procedures used to develop summary values in SAR Sections 2.1, 2.3.1, 2.3.2, 2.3.3, and 2.4. The summary values are derived from (i) different modeling domains, (ii) infiltration uncertainty scenarios, (iii) unadjusted and adjusted net infiltration weights (for the latter, GLUE-derived weights), (iv) areas based on the entire repository or percolation region and seeping environment, (v) different rock types, and (vi) calculations from an example exercise.

1. RESPONSE

This response provides a summary of a consistent set of values to use in a comparison of precipitation and the resulting water flux through the mountain and the repository horizon. Table 1 summarizes precipitation, infiltration, percolation, and seepage values averaged over the repository footprint for each infiltration case (10th, 30th, 50th, and 90th percentiles) and climate state. Table 1 also includes mean values calculated using the generalized likelihood uncertainty estimation (GLUE) methodology weighting factors (SAR Section 2.3.2.4.1.2.4.5) for the percolation and seepage rates, as well as for the unsaturated zone flow model upper boundary net infiltration. The values in Table 1 for precipitation and net infiltration are consistent with the percolation flux values and the TSPA model seepage results. The seepage results in Table 1 are averaged over the repository footprint over both seeping and nonseeping waste package locations.

Sections 1.1 to 1.3 outline the relationship between precipitation, net infiltration, percolation, and seepage, including a discussion of the consistency between the values presented in Table 1 and those in the SAR for the different modeling domains and infiltration cases.

- Section 1.1 discusses the precipitation and net infiltration results from the Infiltration Model presented in SAR Section 2.3.1.

- Section 1.2 discusses the unsaturated zone flow model upper boundary net infiltration and percolation results at the base of the Upper Paintbrush nonwelded vitric (PTn) unit. These results are presented in SAR Section 2.3.2.

- Section 1.3 presents the average repository percolation and seepage results for the nominal and seismic ground motion cases, including the average seepage fractions, for each percolation subregion and for each climate state. Repository average results for the multiscale thermal-hydrologic model (MSTHM) percolation rates at the base of the PTn unit and TSPA seepage model results are presented in SAR Sections 2.1, 2.3.5, and 2.4.

Table 1. Precipitation, Net Infiltration, Percolation, and Seepage Averaged over the Repository Footprint

Infiltration Percentile[a]	Climate State	Precipitation (mm/yr)[b]	Unsaturated Zone Flow Model Upper Boundary Net Infiltration (mm/yr)[c]	MSTHM Percolation at the Base of PTn[d]		Seepage (m^3/yr per waste package)[e]	
			2007	mm/yr	m^3/yr per Waste Package	Nominal	Seismic
10th ***p*** **= 0.6191**	Present-Day	150.9	4.0	4.09	0.115	0.001	0.001
	Monsoon	216.2	7.8	7.82	0.219	0.005	0.006
	Glacial-Transition	284.4	11.9	12.14	0.341	0.016	0.020
	Post-10,000-year	—	21.29	21.50	0.603	0.042	0.241
30th ***p*** **= 0.1568**	Present-Day	168.2	10.1	10.23	0.287	0.008	0.008
	Monsoon	157.8	16.0	16.11	0.452	0.026	0.027
	Glacial-Transition	277.3	25.9	26.28	0.737	0.070	0.082
	Post-10,000-year	—	39.52	40.37	1.132	0.148	0.612
50th ***p*** **= 0.1645**	Present-Day	198.2	14.5	14.63	0.410	0.015	0.016
	Monsoon	252.1	19.4	19.53	0.548	0.037	0.037
	Glacial-Transition	233.6	35.5	36.17	1.015	0.109	0.123
	Post-10,000-year	—	51.05	51.78	1.452	0.195	0.804
90th ***p*** **= 0.0596**	Present-Day	222.7	33.8	34.08	0.956	0.072	0.074
	Monsoon	324.7	91.8	92.4	2.592	0.438	0.446
	Glacial-Transition	300.0	68.9	69.69	1.955	0.278	0.312
	Post-10,000-year	—	61.03	61.60	1.728	0.226	0.960
Unweighted Mean Results[f]	Present-Day	181.8	17.31	—	—	—	—
	Monsoon	288.1	38.12	—	—	—	—
	Glacial-Transition	296.7	38.88	—	—	—	—
	Post-10,000-year	—	—	—	—	—	—
Weighted Mean Results	Present-Day	—	8.46	8.57	0.24	0.01	0.01
	Monsoon	—	16.00	16.09	0.45	0.04	0.04
	Glacial-Transition	—	21.37	21.74	0.61	0.06	0.06
	Post-10,000-year	—	31.41	31.83	0.89	0.10	0.43

NOTE: Precipitation over repository footprint equals precipitation over infiltration domain multiplied by 1.047.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration cases: SAR Section 2.3.2.4.1.2.4.5.5.
[b] SAR Tables 2.3.1-2, 2.3.1-3, and 2.3.1-4.
[c]Unsaturated zone flow model results for the average upper boundary net infiltration over the 2007 repository footprint. Post-10,000-year values from SAR Table 2.3.2-15.
[d] Data extracted from the MSTHM input to the TSPA model, SAR Section 2.3.5.4.1.3.2. The percolation flux (m^3/yr) was calculated using the cross-sectional area used in the calculation of seepage in the TSPA model (5.5-m drift diameter × 5.1-m waste package length).
[e]The seepage values were extracted from the nominal and seismic ground motion modeling cases for 1,000,000 years.
[f]SAR Tables 2.3.1-2, 2.3.1-3, and 2.3.1-4. Unweighted Mean net infiltration is based on unweighted probability of the infiltration percentiles (0.2, 0.2, 0.3, and 0.3) documented in SAR Section 2.3.2.4.1.2.4.5.1.

1.1 PRECIPITATION AND NET INFILTRATION SUMMARY RESULTS

Table 2 presents precipitation and net infiltration results for each pre-10,000-year climate state. These results are spatially averaged over the infiltration model domain and over the vertical projection of the 2002 repository footprint for each of the four infiltration percentile maps used in the TSPA model. The unweighted mean precipitation and net infiltration values in Table 2 are based on all 40 realizations of the infiltration model (SAR Section 2.3.1.3.3.1.2, p. 2.3.1-67). In addition, Table 2 presents the weighted mean net infiltration using GLUE methodology weighting factors (SAR Section 2.3.2.4.1.2.4.5). As discussed in SAR Section 2.3.2.4.1.2.4.5.1, the 10th, 30th, 50th, and 90th percentile infiltration maps from the infiltration model have prior weights of 0.2, 0.2, 0.3, and 0.3, respectively. The resulting weights after calibration, using the GLUE methodology, are 0.6191, 0.1568, 0.1645, and 0.0596, respectively. SAR Section 2.1 (p. 2.1-18) includes a discussion of the estimated average net infiltration ranges as a percentage of the precipitation, consistent with the data presented in SAR Section 2.3.1 and Table 2, averaged over the infiltration model domain. A significant reduction of precipitation is reflected in the ratio of net infiltration to precipitation included in Table 2 and also in the ratio of percolation to precipitation shown in Table 11.

It should be noted that the precipitation values in Tables 1 and 2 correspond to specific realizations of the infiltration model (Mass Accounting System for Soil Infiltration and Flow – MASSIF) selected as representative of the 10th, 30th, 50th, and 90th percentile net infiltration cases; they do not represent the respective percentiles of precipitation. The precipitation value presented for the realization selected for the 10th percentile net infiltration map for the monsoon climate state is larger than the precipitation value for the 30th percentile net infiltration map. The same is observed when comparing the precipitation presented for 10th, 30th, and 50th percentile net infiltration maps selected for the glacial-transition climate. This is due to differences in the sampled values uncertain parameters used in each of the 40 infiltration model realizations. Some of the parameters that were varied included stochastic parameters describing precipitation. It is also noteworthy that the maximum value of average annual precipitation for the monsoon climate is larger than that for the glacial-transition climate, because more extreme precipitation events are predicted for the monsoon than for glacial-transition climate.

The infiltration model provides four net infiltration maps to serve as the upper boundary condition flux for the site-scale unsaturated zone flow model, (SAR Section 2.3.2.4.1.2.4.5) for each of the three climate states in the pre-10,000-year period: present-day, monsoon, and glacial-transition. SAR Figure 2.3.1-2 portrays the information transfer within the TSPA model over the three modeled climate states. These maps represent the 10th, 30th, 50th, and 90th percentile infiltration conditions. Uncertainty in infiltration is incorporated through the selection of the net infiltration maps corresponding to one of the four infiltration conditions in each TSPA realization. The mean values for each infiltration percentile map presented in Table 2 represent the mean over the infiltration percentile for each of the three 10,000-year climate states used in the TSPA model. SAR Section 2.4.1 describes the implementation and integration of the infiltration model outputs into the TSPA model.

Table 2. Average Precipitation and Net Infiltration Rates over the pre-10,000-year Period

Infiltration Map Percentile[a]	Climate State	Infiltration Model Domain[b]			2002 Repository Footprint[b,c]		
		Precipitation (mm/yr)	Net Infiltration (mm/yr)	Ratio of Net Infiltration to Precipitation (%)	Precipitation (mm/yr)	Net Infiltration (mm/yr)	Ratio of Net Infiltration to Precipitation (%)
10th *p* = 0.6191	Present-Day	144.1	3.9	2.71	150.9	3.9	2.58
	Monsoon	206.5	6.3	3.05	216.2	6.2	2.87
	Glacial-Transition	271.7	13.2	4.86	284.4	8.5	2.99
30th *p* = 0.1568	Present-Day	160.6	7.3	4.55	168.2	6.5	3.86
	Monsoon	150.7	14.4	9.56	157.8	18.9	11.98
	Glacial-Transition	264.8	22.8	8.61	277.3	25.6	9.23
50th *p* = 0.1645	Present-Day	189.3	13	6.87	198.2	10.9	5.76
	Monsoon	240.8	22.9	9.51	252.1	28.8	11.42
	Glacial-Transition	223.1	28.6	12.82	233.6	40.5	17.34
90th *p* = 0.0596	Present-Day	212.7	26.7	12.55	222.7	34.4	16.17
	Monsoon	310.2	52.6	16.96	324.7	74.5	22.94
	Glacial-Transition	286.6	47	16.40	300	68.8	22.93
Unweighted Mean Results[d]							
	Present-Day	173.6	14.30	8.24	181.8	17.6	9.68
	Monsoon	275.2	25.50	9.27	288.1	32.9	11.42
	Glacial-Transition	283.4	30.00	10.59	296.7	38.7	13.04
GLUE-Weighted Mean Results[e]							
	Present-Day	—	7.29	—	—	7.28	—
	Monsoon	—	13.06	—	—	15.98	—
	Glacial-Transition	—	19.25	—	—	20.04	—

NOTE: Precipitation over repository footprint equals precipitation over infiltration domain multiplied by 1.047 (ratio that accounts for the mean elevation difference between the repository footprint cells and the entire infiltration modeling domain cells).

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration cases: SAR Section 2.3.2.4.1.2.4.5. [b] SAR Tables 2.3.1-2, 2.3.1-3, and 2.3.1-4.
[c]Repository Footprint Results extracted from the Infiltration Model results documented in SAR 2.3.1.3.3.1.2.
[d]SAR Tables 2.3.1-2, 2.3.1-3, and 2.3.1-4. Unweighted Mean values are averaged over all 40 realizations of the infiltration model.
[e]GLUE-weighted results calculated using the probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration cases.

1.2 UNSATURATED ZONE FLOW MODEL UPPER BOUNDARY NET INFILTRATION AND PERCOLATION SUMMARY RESULTS

For the pre-10,000-year period, the site-scale unsaturated zone flow model uses the 10th, 30th, 50th, and 90th percentile net infiltration maps for the present and two future climate states as input to produce steady-state percolation flow fields and distribution of percolation fluxes for use in the TSPA (SAR Section 2.3.2.4.1.2.4.2). For the post-10,000-year period, the site-scale unsaturated zone flow model provides four additional steady-state percolation flow fields for which the spatially averaged percolation at the repository horizon represents the distribution of deep percolation rates specified in 10 CFR 63.342(c)(2) (SAR Section 2.3.2.4.1.2.4.2). As described in SAR Section 2.3.2.4.1.2.4.2, a set of maps for the net infiltration boundary condition is developed to spatially distribute water flux while matching the specified average percolation rates. This is done using the infiltration maps for the pre-10,000-year period and scaling the net infiltration rates such that the average net infiltration rate over the 2007 repository footprint matches the target average percolation flux rates in the repository footprint selected to represent the log-uniform distribution. The post-10,000-year percolation results are based upon the proposed log-uniform (13 to 64 mm/yr) distribution, not the truncated log-normal (10 to 100 mm/yr) as revised in the final rule. The results presented in this response are consistent with the SAR and TSPA model results and therefore do not include the change in the distribution for the deep percolation rates.

SAR Table 2.3.2-27 summarizes the net infiltration for all climate states averaged over the unsaturated zone flow model domain; these results are included in Table 3 for comparison with the repository footprint average net infiltration results. Table 3 presents results for both the older 2002 repository footprint used to calculate the average infiltration model results presented in Table 2, and the current repository footprint, used in 2007 for the License Application. Both repository footprint averages are presented in Table 3 for comparison with SAR Section 2.3.1 and to provide a consistent set of values over the same spatial domain. The infiltration results presented in Table 2 are calculated using a vertical projection of a 2002 version of the repository footprint, consistent with SAR Tables 2.3.1-2, 2.3.1-3, and 2.3.1-4, rather than the 2007 repository footprint used in the TSPA model. Since the 2002 repository footprint was used only for qualitative discussions of the infiltration model results and the difference between the average net infiltrations over the footprints is small (as presented in Table 3); the summary infiltration model results were not updated for the 2007 repository footprint in the supporting documentation or in SAR Section 2.3.1. The downstream models were unaffected since the net infiltration boundary flux was extracted from the net infiltration maps for the entire unsaturated zone model domain.

The unsaturated zone flow model provides percolation flux at the base of the PTn unit to the MSTHM, as well as providing the three-dimensional flow fields used by the unsaturated zone transport model component of the TSPA model (SAR Sections 2.3.5; SNL 2008, Section 6.3.2). The percolation rates over the repository footprint are spatially interpolated from the unsaturated zone model domain to the 3,624 MSTHM subdomain locations (SAR Sections 2.3.3.2.3.5 and 2.3.2). Table 3 provides a summary of the percolation rates over the repository footprint extracted from the unsaturated zone flow model and from the MSTHM. There are only minor differences in these average values as a result of the spatial interpolation between the unsaturated zone flow model domain and the MSTHM subdomain locations.

SAR Figure 2.3.2-1 shows the information flow diagram for development of the site-scale unsaturated zone flow model, and SAR Figure 2.3.2-2 shows the information transfer among the principal model components for the TSPA nominal modeling case. The unsaturated zone flow model provides the unsaturated zone flow fields used in the TSPA model unsaturated zone transport calculations. In addition, for each infiltration boundary condition and climate state, the site-scale unsaturated zone flow model provides the following outputs to the MSTHM (SAR Section 2.4.2.3.2.1): (1) the percolation flux at the base of the PTn unit above each subdomain location, (2) the three-dimensional numerical grid, and (3) associated unsaturated zone hydrologic properties. The percolation values used in the MSTHM are spatially interpolated from the 16 unsaturated zone flow fields and are passed from the MSTHM to the TSPA model to predict seepage into emplacement drifts under ambient and thermally perturbed conditions (SNL 2008, Section 6.3.3.1.2).

Table 3. Unsaturated Zone Flow Model Results

Unsaturated Zone Flow Model Domain			Repository Footprint			
Infiltration Map Percentile[a]	Climate State	Net Infiltration (mm/yr)[b]	Unsaturated Zone Flow Model Upper Boundary Net Infiltration (mm/yr)		Unsaturated Zone Flow Model Percolation at Base of PTn (mm/yr)[e]	MSTHM Percolation at Base of PTn (mm/yr)[f]
			2002[c]	2007[d]		
10th ***p* = 0.6191**	Present-Day	3.03	3.9	4.0	4.1	4.09
	Monsoon	6.74	6.2	7.8	7.8	7.82
	Glacial-Transition	11.03	8.5	11.9	12.2	12.14
	Post-10,000-year	16.89	—	21.29	21.58	21.50
30th ***p* = 0.1568**	Present-Day	7.96	6.5	10.1	10.2	10.23
	Monsoon	12.89	18.9	16.0	16.1	16.11
	Glacial-Transition	20.45	25.6	25.9	26.3	26.28
	Post-10,000-year	28.99	—	39.52	40.76	40.37
50th ***p* = 0.1645**	Present-Day	12.28	10.9	14.5	14.6	14.63
	Monsoon	15.37	28.8	19.4	19.5	19.53
	Glacial-Transition	25.99	40.5	35.5	36.2	36.17
	Post-10,000-year	34.67	—	51.05	52.07	51.78
90th ***p* = 0.0596**	Present-Day	26.78	34.4	33.8	34.1	34.08
	Monsoon	73.26	74.5	91.8	92.4	92.40
	Glacial-Transition	46.68	68.8	68.9	69.7	69.69
	Post-10,000-year	48.84	—	61.03	61.86	61.60
Mean Results	Present-Day	6.74	7.28	8.46	8.57	8.57
	Monsoon	13.09	15.98	16.00	16.07	16.09
	Glacial-Transition	17.09	20.04	21.37	21.79	21.74
	Post-10,000-year	23.62	—	31.41	32.00	31.83

NOTE: Mean results for the pre-10,000 year climates are GLUE weighted. Post-10,000 year Mean Results represent the sample mean of the percolation resulting from approximating the distribution of deep percolation by four discrete values. The GLUE weighting factors are used to select these four discrete values.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations SAR Section 2.3.2.4.1.2.4.5.5. [b]Average net infiltration over the unsaturated zone model domain, SAR Tables 2.3.2-27.[c]Infiltration model results over the repository footprint from Table 2 using a 2002 repository footprint, SAR Section 2.3.1.3.3.2. [d]Unsaturated Zone Flow Model Results for the Upper Boundary Net Infiltration over the 2007 Repository Footprint. Post-10,000-year values from SAR Table 2.3.2-15. [e]Unsaturated zone flow model results for the average percolation over the repository footprint and Table H-2 of SNL 2007. Post-10,000-year values from Fig. 6.1-6 (SNL 2007). [f] Data extracted from the MSTHM input to the TSPA model, SAR Section 2.3.5.4.1.3.

1.3 SEEPAGE SUMMARY RESULTS USED IN THE TSPA MODEL CALCULATIONS

As shown in SAR Figure 2.3.3-1, information needed for the implementation of the drift seepage submodel in the TSPA model is provided by two TSPA model components: (1) the Engineered Barrier System (EBS) thermal-hydrologic environment submodel (SNL 2008, Section 6.3.2), and (2) the seismic damage submodel (SNL 2008, Section 6.6). The EBS thermal-hydrologic environment submodel contains the MSTHM provided percolation flux values interpolated at various locations throughout the repository (SAR Section 2.3.3.2.3.5) from the flux distributions for current and future climate states calculated by the site-scale unsaturated zone flow model (SAR Section 2.3.2). The EBS thermal-hydrologic environment submodel also provides the evolution of drift-wall temperature at each repository location, which is required to evaluate whether thermal seepage is limited by a vaporization barrier (SAR Section 2.3.3.3.4). The TSPA submodel for the seismic damage abstraction provides cumulative rockfall volumes in response to single or multiple seismic events, which describe the degree of drift degradation and its impact on seepage (SAR Section 2.3.3.2.4.2.2).

Table 4 contains average percolation fluxes used in the TSPA model to calculate the drift seepage for each infiltration case at each climate state, including an average percolation rate over the repository footprint as well as for each repository percolation subregion. The flux quantile values for each percolation subregion are also provided in the table. The weighted repository average percolation rate is shown on SAR Figure 2.1-5 and included in Table 4.

The TSPA drift seepage submodel calculates the seepage rate (average seepage per waste package in a seeping environment) as a function of time for each repository subregion for the nominal and seismic ground motion modeling cases (Section 6.3.3, SNL 2008). The probabilistic seepage calculation in the TSPA is a function of the local percolation and the ambient and thermal components of the drift seepage abstraction, as described in SAR Sections 2.3.3.2.4 and 2.3.3.3.4. Tables 5 through 10 contain TSPA model seepage results extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps to illustrate the temporal variation in seepage between the present-day, monsoon, glacial-transition, and post-10,000-year climate states, respectively. Seepage results for the nominal modeling case represents the average seepage rate over the epistemic uncertainties (conditional on one infiltration map) in the absence of disruptive events (e.g., igneous or seismic events). In addition, to demonstrate the impact of drift degradation, seepage results from the seismic ground motion modeling case are presented; these results are averaged over the epistemic uncertainties (conditional on one infiltration map) as well as the aleatory uncertainty in seismic events. Table 5 contains the TSPA nominal scenario modeling case seepage results in terms of flux per waste package for each infiltration case at each climate state, including an average over the repository footprint as well as an average for each repository subregion, including both seeping and non-seeping environments. The average seepage fractions (the fraction of waste packages in a percolation subregion experiencing seepage) are also presented in Table 5. Tables 6 and 7 provide the average seepage per waste package in a seeping environment for commercial spent nuclear fuel (SNF) and codisposal waste packages.

Table 8 contains the TSPA seismic ground motion modeling case seepage results. These seepage rates account for seismic-induced drift collapse, which increases the seepage rates over time until the drift is fully degraded, as demonstrated in SAR Figure 2.1-5. It should be noted in the seismic ground motion case results that the selection of seepage data extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps to demonstrate the temporal variation in seepage for each climate state, maximizes the effects of drift degradation on seepage for the glacial-transition and post-10,000-year climates by extracting the seepage values at the end of these climate states; at the 10,000- and 1,000,000-year time steps respectively. Tables 9 and 10 contain the commercial SNF and codisposal seismic seepage rate per waste package in a seeping environment. The seepage fractions are presented as calculated for the post-10,000-year climate, as used in the 1,000,000 year TSPA model. Since the seepage fractions are calculated at 1,000,000 years, the high fractions in the seismic ground motion modeling case reflect the increase in seepage due to seismic induced drift degradation. These seepage fractions are consistent with SAR Tables 2.1-6 to 2.1-9, which include the TSPA nominal and seismic ground motion modeling case seepage fractions for the glacial-transition climate and the post-10,000-year period. SAR Figure 2.3.3-47 presents the mean seepage rates as a function of time for the four infiltration scenarios consistent with the repository average results presented in Table 5. SAR Figure 2.1-5 plots the mean seepage over the repository, consistent with the weighted mean data presented in Tables 5 and 8 for the nominal and seismic ground motion modeling cases.

The tabulated TSPA model results show that higher infiltration scenarios result in more seepage in both the nominal and seismic ground motion modeling cases, as described in SAR Section 2.3.3.4.2 and shown in SAR Figures 2.3.3-47 to 2.3.3-49. As presented in Table 11, over all waste packages, the repository average amount of seeping water weighted by the relative probability for each infiltration case is approximately 0.01, 0.04, and 0.06 m^3/yr per waste package for the present-day, monsoon, and glacial-transition climate states, respectively. The corresponding ratio of seepage to percolation over the pre-10,000-year time period included on Table 11 is between approximately 4% and 10% for the repository average TSPA seepage over all infiltration maps. These results confirm that over the pre-10,000-year time period, about 90% to 96% of the percolation flux would be diverted around an intact drift, on average. For the post-10,000-year period over all waste packages, the repository average amount of seeping water weighted by the relative probability for each infiltration case is approximately 0.1 and 0.43 m^3/yr per waste package for the nominal and seismic ground motion modeling cases, respectively, at 1,000,000 years. The corresponding ratio of seepage to percolation over the post-10,000 year time period are approximately 11% and 49% for the nominal and seismic ground motion modeling cases respectively. On average, about 89% of the percolation flux would be diverted around a drift in the nominal modeling cases, whereas only 51% of the percolation flux would be diverted around a fully degraded drift at 1,000,000 years in the seismic ground motion modeling case. Drift degradation also results in a significant increase in the fraction of waste packages that encounter seeping conditions from 40% in the nominal case to 69% in the seismic ground motion modeling case based on the comparison of the seepage fraction shown in Tables 5 and 8 (SAR Section 2.4.2.2.1.2.2.1; SNL 2008, Tables 8.3-3[a] and 8.3-5[a]).

Table 4. Average Percolation Flux Used in the TSPA Calculations

Infiltration Map Percentile[a]	Climate State	MSTHM Percolation at Base of PTn Subregion Rates[b,c] (mm/yr)					MSTHM Repository Average Percolation at Base of PTn	
		1 (0.05)	2 (0.25)	3 (0.4)	4 (0.25)	5 (0.05)	(mm/yr)	(m^3/yr per waste package)
10th ***p* = 0.6191**	Present-Day	0.49	2.33	4.32	5.68	6.71	4.09	0.115
	Monsoon	1.23	5.38	8.31	10.00	11.72	7.82	0.219
	Glacial-Transition	0.68	3.72	11.06	20.93	30.46	12.14	0.341
	Post-10,000-year	2.56	15.06	23.32	26.94	30.90	21.50	0.603
30th ***p* = 0.1568**	Present-Day	1.58	6.50	10.84	13.59	15.81	10.23	0.287
	Monsoon	2.34	10.68	17.03	21.24	24.06	16.11	0.452
	Glacial-Transition	2.51	13.53	27.15	38.29	46.90	26.28	0.737
	Post-10,000-year	2.55	17.46	41.50	61.55	77.82	40.37	1.132
50th ***p* = 0.1645**	Present-Day	2.22	9.76	15.55	18.87	22.79	14.63	0.410
	Monsoon	2.29	11.22	20.38	26.62	36.14	19.53	0.548
	Glacial-Transition	2.45	15.71	37.17	55.09	69.65	36.17	1.015
	Post-10,000-year	4.29	29.85	55.67	70.47	84.28	51.78	1.452
90th ***p* = 0.0596**	Present-Day	4.942	24.08	36.87	42.53	48.59	34.08	0.956
	Monsoon	12.52	65.45	99.91	115.5	131.51	92.40	2.592
	Glacial-Transition	5.84	40.30	74.93	94.78	113.20	69.69	1.955
	Post-10,000-year	8.81	43.74	66.56	76.91	87.51	61.60	1.728
Mean Results								
	Present-Day	1.21	5.51	9.13	11.28	13.28	8.57	0.24
	Monsoon	2.25	10.76	17.12	20.79	24.81	16.09	0.45
	Glacial-Transition	1.57	9.41	21.69	33.67	44.41	21.74	0.61
	Post-10,000-year	3.22	19.58	34.07	42.51	50.41	31.83	0.89

NOTE: The percolation flux (m^3/yr) was calculated using the cross-sectional area used in the calculation of seepage in the TSPA model (5.5-m drift diameter × 5.1-m waste package length). Mean results for the pre-10,000 year climates are GLUE weighted. Post-10,000 year Mean Results represent the sample mean of the percolation resulting from approximating the distribution of deep percolation by four discrete values. The GLUE weighting factors are used to select these four discrete values.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations: SAR Section 2.3.2.4.1.2.4.5.5.
[b]Data extracted from the MSTHM input to the TSPA model, SAR Section 2.3.5.4.1.3.2.
[c]Percolation subregions and quantile ranges SAR Section 2.4.2.3.2.1.2.

Table 5. Nominal Modeling Case Average Seepage Rate and Fraction Summary

TSPA Average Seepage for the Nominal Modeling Case 1,000,000 Years – Repository Footprint							
Infiltration Map Percentile[a]	**Climate State**	**Average Flux over the Subregion[b,c] (m^3/yr per waste package)**					**Repository Average (m^3/yr per waste package)**
		1 (0.05)	**2 (0.25)**	**3 (0.4)**	**4 (0.25)**	**5 (0.05)**	
10th p = 0.6191	Present-Day	2.66×10^{-5}	4.81×10^{-4}	9.24×10^{-4}	1.20×10^{-3}	2.33×10^{-3}	0.001
	Monsoon	3.20×10^{-4}	3.53×10^{-3}	5.82×10^{-3}	6.40×10^{-3}	1.07×10^{-2}	0.005
	Glacial-Transition	7.97×10^{-5}	1.50×10^{-3}	1.14×10^{-2}	3.15×10^{-2}	6.92×10^{-2}	0.016
	Post-10,000-year	2.04×10^{-3}	2.79×10^{-2}	4.76×10^{-2}	4.97×10^{-2}	7.23×10^{-2}	0.042
	Seepage Fraction	*0.099*	*0.295*	*0.370*	*0.359*	*0.415*	*0.337*
30th p = 0.1568	Present-Day	4.24×10^{-4}	4.90×10^{-3}	8.16×10^{-3}	1.02×10^{-2}	1.68×10^{-2}	0.008
	Monsoon	1.52×10^{-3}	1.63×10^{-2}	2.81×10^{-2}	3.38×10^{-2}	4.75×10^{-2}	0.026
	Glacial-Transition	1.71×10^{-3}	2.51×10^{-2}	7.10×10^{-2}	1.09×10^{-1}	1.68×10^{-1}	0.070
	Post-10,000-year	1.57×10^{-3}	3.91×10^{-2}	1.46×10^{-1}	2.42×10^{-1}	3.84×10^{-1}	0.148
	Seepage Fraction	*0.135*	*0.356*	*0.517*	*0.553*	*0.622*	*0.472*
50th p = 0.1645	Present-Day	8.27×10^{-4}	1.05×10^{-2}	1.64×10^{-2}	1.81×10^{-2}	3.13×10^{-2}	0.015
	Monsoon	1.07×10^{-3}	1.66×10^{-2}	3.89×10^{-2}	4.92×10^{-2}	9.21×10^{-2}	0.037
	Glacial-Transition	1.17×10^{-3}	2.84×10^{-2}	1.07×10^{-1}	1.78×10^{-1}	2.89×10^{-1}	0.109
	Post-10,000-year	3.98×10^{-3}	9.08×10^{-2}	2.14×10^{-1}	2.69×10^{-1}	3.93×10^{-1}	0.195
	Seepage Fraction	*0.160*	*0.416*	*0.538*	*0.545*	*0.600*	*0.493*
90th p = 0.0596	Present-Day	4.71×10^{-3}	5.17×10^{-2}	8.06×10^{-2}	8.08×10^{-2}	1.24×10^{-1}	0.072
	Monsoon	3.11×10^{-2}	2.99×10^{-1}	4.90×10^{-1}	5.19×10^{-1}	7.09×10^{-1}	0.438
	Glacial-Transition	6.60×10^{-3}	1.30×10^{-1}	3.06×10^{-1}	3.77×10^{-1}	5.62×10^{-1}	0.278
	Post-10,000-year	1.61×10^{-2}	1.56×10^{-1}	2.54×10^{-1}	2.64×10^{-1}	3.72×10^{-1}	0.226
	Seepage Fraction	*0.269*	*0.555*	*0.646*	*0.638*	*0.687*	*0.605*
TSPA Mean Results	Present-Day	5.00×10^{-4}	5.88×10^{-3}	9.36×10^{-3}	1.02×10^{-2}	1.66×10^{-2}	0.009
	Monsoon	2.48×10^{-3}	2.54×10^{-2}	4.38×10^{-2}	4.84×10^{-2}	7.16×10^{-2}	0.040
	Glacial-Transition	9.06×10^{-4}	1.73×10^{-2}	5.40×10^{-2}	8.83×10^{-2}	1.50×10^{-1}	0.056
	Post-10,000-year	3.12×10^{-3}	4.76×10^{-2}	1.03×10^{-1}	1.28×10^{-1}	1.91×10^{-1}	0.095
	Seepage Fraction	*0.125*	*0.340*	*0.437*	*0.437*	*0.494*	*0.400*

NOTE: TSPA seepage data extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps for the present-day, monsoon, glacial-transition, and post-10,000-year climate states, respectively. The data was extracted from the TSPA Nominal Modeling Case for 1,000,000 years and is averaged over the epistemic uncertainties.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations: SAR Section 2.3.2.4.1.2.4.5.5.
[b]The seepage values were extracted from the Nominal 1,000,000-year modeling case.
[c]Percolation subregions and quantile ranges SAR Section 2.4.2.3.2.1.2

Table 6. Nominal Modeling Case Commercial SNF Waste Package Average Seepage Rates and Fractions in a Seeping Environment

Nominal Seepage - Commercial SNF Waste Packages in Seeping Environment							
Infiltration Map Percentile[a]	**Climate State**	**Average Flux over the Subregion[b,c] (m^3/yr per waste package)**					**Repository Average (m^3/yr per waste package)**
		1 (0.05)	**2 (0.25)**	**3 (0.4)**	**4 (0.25)**	**5 (0.05)**	
10th ***p* = 0.6191**	Present-Day	0.0002	0.0013	0.0020	0.0026	0.0050	0.0020
	Monsoon	0.0025	0.0108	0.0139	0.0151	0.0236	0.0134
	Glacial-Transition	0.0006	0.0043	0.0278	0.0820	0.1617	0.0408
	Post-10,000-year	0.0210	0.0956	0.1264	0.1321	0.1710	0.1171
	Seepage Fraction	*0.099*	*0.295*	*0.370*	*0.359*	*0.416*	*0.337*
30th ***p* = 0.1568**	Present-Day	0.0023	0.0118	0.0132	0.0146	0.0241	0.0132
	Monsoon	0.0107	0.0425	0.0480	0.0507	0.0692	0.0465
	Glacial-Transition	0.0116	0.0653	0.1241	0.1722	0.2496	0.1221
	Post-10,000-year	0.0096	0.1030	0.2616	0.3976	0.58442	0.2595
	Seepage Fraction	*0.134*	*0.356*	*0.516*	*0.553*	*0.621*	*0.472*
50th ***p* = 0.1645**	Present-Day	0.0038	0.0225	0.0264	0.0274	0.0463	0.0255
	Monsoon	0.0052	0.0365	0.0656	0.0784	0.1382	0.0622
	Glacial-Transition	0.0058	0.0618	0.1831	0.3002	0.4553	0.1868
	Post-10,000-year	0.0226	0.2107	0.3784	0.4618	0.6273	0.3520
	Seepage Fraction	*0.161*	*0.416*	*0.538*	*0.545*	*0.601*	*0.494*
90th ***p* = 0.0596**	Present-Day	0.0152	0.0858	0.1131	0.1145	0.1666	0.1044
	Monsoon	0.1142	0.5246	0.7362	0.7871	1.0094	0.6786
	Glacial-Transition	0.0224	0.2243	0.4551	0.5689	0.7970	0.4213
	Post-10,000-year	0.0568	0.2690	0.3777	0.3953	0.5225	0.3461
	Seepage Fraction	*0.270*	*0.556*	*0.647*	*0.638*	*0.689*	*0.605*
TSPA Mean Results	Present-Day	0.0020	0.0115	0.0144	0.0152	0.0244	0.0138
	Monsoon	0.0110	0.0508	0.0710	0.0773	0.1086	0.0664
	Glacial-Transition	0.0044	0.0364	0.0939	0.1610	0.2615	0.1002
	Post-10,000-year	0.0216	0.1260	0.2038	0.2433	0.3314	0.1915
	Seepage Fraction	*0.125*	*0.340*	*0.437*	*0.436*	*0.494*	*0.400*

NOTE: TSPA seepage data extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps for the present-day, monsoon, glacial-transition, and post-10,000-year climate states, respectively. The data was extracted from the TSPA Nominal Modeling Case for 1,000,000 years and is averaged over the epistemic uncertainties.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations: SAR Section 2.3.2.4.1.2.4.5.5.
[b]The seepage values were extracted from the Nominal 1,000,000-year modeling case.
[c]Percolation subregions and quantile ranges SAR Section 2.4.2.3.2.1.2.

Table 7. Nominal Modeling Case Codisposal Waste Package Average Seepage Rates and Fractions in a Seeping Environment

Nominal Seepage – Codisposal Waste Packages in Seeping Environment							
Infiltration Map Percentile[a]	**Climate State**	**Average Flux over the Subregion[b,c] (m^3/yr per waste package)**					**Repository Average (m^3/yr per waste package)**
		1 (0.05)	**2 (0.25)**	**3 (0.4)**	**4 (0.25)**	**5 (0.05)**	
10th *p* = 0.6191	Present-Day	0.0002	0.0015	0.0024	0.0033	0.0057	0.0025
	Monsoon	0.0030	0.0109	0.0148	0.0162	0.0243	0.0140
	Glacial-Transition	0.0006	0.0042	0.0280	0.0823	0.1598	0.0408
	Post-10,000-year	0.0221	0.0935	0.1268	0.1325	0.1688	0.1168
	Seepage Fraction	*0.100*	*0.295*	*0.371*	*0.359*	*0.414*	*0.337*
30th *p* = 0.1568	Present-Day	0.0027	0.0137	0.0155	0.0171	0.0259	0.0153
	Monsoon	0.0102	0.0442	0.0499	0.0527	0.0684	0.0481
	Glacial-Transition	0.0109	0.0663	0.1239	0.1718	0.2424	0.1218
	Post-10,000-year	0.0098	0.1043	0.2619	0.3975	0.5750	0.2594
	Seepage Fraction	*0.137*	*0.357*	*0.519*	*0.554*	*0.624*	*0.473*
50th *p* = 0.1645	Present-Day	0.0051	0.0241	0.0316	0.0328	0.0512	0.0297
	Monsoon	0.0054	0.0359	0.0664	0.0785	0.1379	0.0623
	Glacial-Transition	0.0061	0.0608	0.1830	0.2940	0.4448	0.1844
	Post-10,000-year	0.0226	0.2084	0.3788	0.4540	0.6116	0.3488
	Seepage Fraction	*0.158*	*0.414*	*0.539*	*0.546*	*0.600*	*0.493*
90th *p* = 0.0596	Present-Day	0.0156	0.0906	0.1241	0.1224	0.1764	0.1125
	Monsoon	0.1105	0.5293	0.7373	0.7877	1.0042	0.6799
	Glacial-Transition	0.0211	0.2234	0.4535	0.5648	0.7882	0.4189
	Post-10,000-year	0.0537	0.2699	0.3765	0.3918	0.5175	0.3446
	Seepage Fraction	*0.265*	*0.554*	*0.643*	*0.637*	*0.680*	*0.602*
TSPA Mean Results	Present-Day	0.0023	0.0124	0.0165	0.0174	0.0265	0.0155
	Monsoon	0.0110	0.0513	0.0721	0.0784	0.1085	0.0672
	Glacial-Transition	0.0043	0.0363	0.0938	0.1598	0.2570	0.0996
	Post-10,000-year	0.0221	0.1245	0.2041	0.2421	0.3257	0.1907
	Seepage Fraction	*0.125*	*0.339*	*0.438*	*0.436*	*0.493*	*0.400*

NOTE: Climate states: present-day; monsoon, glacial-transition, and post-10,000-year deep percolation rates. TSPA seepage data extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps for the present-day, monsoon, glacial-transition, and post-10,000-year climate states, respectively. The data was extracted from the TSPA Nominal Modeling Case for 1,000,000 years and is averaged over the epistemic uncertainties.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations: SAR Section 2.3.2.4.1.2.4.5.5.
[b]The seepage values were extracted from the Nominal 1,000,000-year modeling case.
[c]Percolation subregions and quantile ranges SAR Section 2.4.2.3.2.1.2.

Table 8. Seismic Ground Motion Modeling Case Average Seepage Rates and Fractions Summary

TSPA Average Seepage for the Seismic GM Modeling Case 1,000,000 Years – Repository Footprint							
Infiltration Map Percentile[a]	**Climate State**	**Average Flux over the Subregion[b,c] (m^3/yr per waste package)**					**Repository Average (m^3/yr per waste package)**
		1	**2**	**3**	**4**	**5**	
		0.05	**0.25**	**0.4**	**0.25**	**0.05**	
10th *p* = 0.6191	Present-Day	4.19×10^{-5}	5.27×10^{-4}	9.87×10^{-4}	1.25×10^{-3}	2.42×10^{-3}	0.001
	Monsoon	3.77×10^{-4}	3.70×10^{-3}	6.02×10^{-3}	6.53×10^{-3}	1.10×10^{-2}	0.006
	Glacial-Transition	5.31×10^{-4}	2.92×10^{-3}	1.52×10^{-2}	3.68×10^{-2}	8.02×10^{-2}	0.020
	Post-10,000-year	3.61×10^{-2}	1.86×10^{-1}	2.74×10^{-1}	2.61×10^{-1}	3.65×10^{-1}	0.241
	Seepage Fraction	*0.441*	*0.608*	*0.667*	*0.640*	*0.695*	*0.636*
30th *p* = 0.1568	Present-Day	4.53×10^{-4}	4.99×10^{-3}	8.30×10^{-3}	1.03×10^{-2}	1.70×10^{-2}	0.008
	Monsoon	1.57×10^{-3}	1.65×10^{-2}	2.85×10^{-2}	3.42×10^{-2}	4.80×10^{-2}	0.027
	Glacial-Transition	3.66×10^{-3}	3.21×10^{-2}	8.35×10^{-2}	1.23×10^{-1}	1.89×10^{-1}	0.082
	Post-10,000-year	3.38×10^{-2}	2.23×10^{-1}	6.27×10^{-1}	9.40×10^{-1}	1.39	0.612
	Seepage Fraction	*0.488*	*0.682*	*0.789*	*0.804*	*0.844*	*0.753*
50th *p* = 0.1645	Present-Day	9.34×10^{-4}	1.08×10^{-2}	1.67×10^{-2}	1.83×10^{-2}	3.16×10^{-2}	0.016
	Monsoon	1.19×10^{-3}	1.70×10^{-2}	3.94×10^{-2}	4.95×10^{-2}	9.27×10^{-2}	0.037
	Glacial-Transition	2.63×10^{-3}	3.45×10^{-2}	1.22×10^{-1}	1.97×10^{-1}	3.18×10^{-1}	0.123
	Post-10,000-year	6.06×10^{-2}	4.37×10^{-1}	8.81×10^{-1}	1.06	1.46	0.804
	Seepage Fraction	*0.503*	*0.717*	*0.799*	*0.797*	*0.831*	*0.765*
90th *p* = 0.0596	Present-Day	5.08×10^{-3}	5.34×10^{-2}	8.32×10^{-2}	8.35×10^{-2}	1.28×10^{-1}	0.074
	Monsoon	3.22×10^{-2}	3.05×10^{-1}	4.99×10^{-1}	5.29×10^{-1}	7.21×10^{-1}	0.446
	Glacial-Transition	1.10×10^{-2}	1.52×10^{-1}	3.44×10^{-1}	4.18×10^{-1}	6.19×10^{-1}	0.312
	Post-10,000-year	1.30×10^{-1}	6.93×10^{-1}	1.07×10^{-1}	1.13	1.46	0.960
	Seepage Fraction	*0.583*	*0.800*	*0.864*	*0.860*	*0.885*	*0.834*
TSPA Mean Results	Present-Day	5.54×10^{-4}	6.07×10^{-3}	9.63×10^{-3}	1.04×10^{-2}	1.70×10^{-2}	0.009
	Monsoon	2.61×10^{-3}	2.60×10^{-2}	4.46×10^{-2}	4.93×10^{-2}	7.27×10^{-2}	0.040
	Glacial-Transition	1.99×10^{-3}	2.16×10^{-2}	6.30×10^{-2}	9.93×10^{-2}	1.68×10^{-1}	0.064
	Post-10,000-year	4.54×10^{-2}	2.63×10^{-1}	4.76×10^{-1}	5.50×10^{-1}	7.69×10^{-1}	0.434
	Seepage Fraction	*0.467*	*0.649*	*0.719*	*0.705*	*0.752*	*0.687*

NOTE: TSPA seepage data extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps for the present-day, monsoon, glacial-transition, and post-10,000-year climate states, respectively. The data was extracted from the TSPA Seismic Ground Motion Modeling Case for 1,000,000 years and is averaged over the epistemic uncertainties.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations: SAR Section 2.3.2.4.1.2.4.5.5.
[b] The seepage values were extracted from the Seismic Ground Motion 1,000,000-year modeling case.
[c]Percolation subregions and quantile ranges SAR Section 2.4.2.3.2.1.2.

Table 9. Seismic Ground Motion Modeling Case Commercial SNF Waste Package Average Seepage Rates and Fractions in a Seeping Environment

Seismic Seepage - Commercial SNF Waste Packages in Seeping Environment							
Infiltration Map Percentile[a]	**Climate State**	**Average Flux over the Subregion**[b,c] **(m^3/yr per waste package)**					**Repository Average (m^3/yr per waste package)**
		1	**2**	**3**	**4**	**5**	
		0.05	**0.25**	**0.4**	**0.25**	**0.05**	
10th ***p* = 0.6191**	Present-Day	0.0001	0.0007	0.0012	0.0015	0.0030	0.001
	Monsoon	0.0008	0.0055	0.0079	0.0085	0.0141	0.007
	Glacial-Transition	0.0012	0.0047	0.0213	0.0519	0.1084	0.028
	Post-10,000-year	0.0845	0.3178	0.4195	0.4090	0.5319	0.380
	Fraction	*0.442*	*0.608*	*0.667*	*0.639*	*0.694*	*0.635*
30th ***p* = 0.1568**	Present-Day	0.0008	0.0064	0.0091	0.0108	0.0183	0.0089
	Monsoon	0.0030	0.0221	0.0325	0.0373	0.0527	0.0306
	Glacial-Transition	0.0074	0.0438	0.0979	0.1386	0.2114	0.0957
	Post-10,000-year	0.072514	0.32587	0.78036	1.1307	1.6117	0.760
	Fraction	*0.487*	*0.682*	*0.788*	*0.803*	*0.844*	*0.753*
50th ***p* = 0.1645**	Present-Day	0.0016	0.0136	0.0184	0.0195	0.0342	0.0174
	Monsoon	0.0022	0.0219	0.0454	0.0557	0.1031	0.0428
	Glacial-Transition	0.0053	0.0450	0.1424	0.2289	0.3636	0.1439
	Post-10,000-year	0.12621	0.6131	1.0961	1.3128	1.7399	1.013
	Fraction	*0.503*	*0.718*	*0.799*	*0.797*	*0.833*	*0.765*
90th ***p* = 0.0596**	Present-Day	0.0081	0.0628	0.0899	0.0904	0.1363	0.0815
	Monsoon	0.0533	0.3680	0.5602	0.5932	0.7938	0.5067
	Glacial-Transition	0.0189	0.1845	0.3884	0.4718	0.6853	0.3547
	Post-10,000-year	0.2318	0.8696	1.2261	1.2932	1.6312	1.1243
	Fraction	*0.584*	*0.800*	*0.864*	*0.861*	*0.886*	*0.834*
TSPA Mean Results	Present-Day	0.0009	0.0075	0.0106	0.0112	0.0185	0.0099
	Monsoon	0.0045	0.0325	0.0511	0.0558	0.0815	0.0468
	Glacial-Transition	0.0039	0.0282	0.0751	0.1196	0.2008	0.0772
	Post-10,000-year	0.0983	0.4004	0.6349	0.7228	0.9643	0.5879
	Fraction	*0.467*	*0.649*	*0.719*	*0.704*	*0.752*	*0.687*

NOTE: TSPA seepage data extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps for the present-day, monsoon, glacial-transition, and post-10,000-year climate states, respectively. The data was extracted from the TSPA Seismic Ground Motion Modeling Case for 1,000,000 years and is averaged over the epistemic uncertainties.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations: SAR Section 2.3.2.4.1.2.4.5.5.
[b]The seepage values were extracted from the Seismic Ground Motion 1,000,000-year modeling case.
[c]Percolation subregions and quantile ranges SAR Section 2.4.2.3.2.1.2.

Table 10. Seismic Ground Motion Modeling Case Codisposal Waste Package Average Seepage Rates and Fractions in a Seeping Environment

Seismic Seepage – Codisposal Waste Packages in Seeping Environment							
Infiltration Map Percentile[a]	**Climate State**	**Average Flux over the Subregion[b,c] (m^3/yr per waste package)**					**Repository Average (m^3/yr per waste package)**
		1	**2**	**3**	**4**	**5**	
		0.05	**0.25**	**0.4**	**0.25**	**0.05**	
10th ***p* = 0.6191**	Present-Day	0.0001	0.0008	0.0015	0.0019	0.0035	0.0015
	Monsoon	0.0009	0.0055	0.0084	0.0091	0.0145	0.0078
	Glacial-Transition	0.0012	0.0047	0.0213	0.0522	0.1069	0.0281
	Post-10,000-year	0.0849	0.3164	0.4199	0.4098	0.5278	0.3802
	Seepage Fraction	*0.440*	*0.608*	*0.667*	*0.641*	*0.697*	*0.636*
30th ***p* = 0.1568**	Present-Day	0.0010	0.0073	0.0108	0.0127	0.0200	0.0104
	Monsoon	0.0029	0.0228	0.0340	0.0389	0.0527	0.0318
	Glacial-Transition	0.0073	0.0440	0.0984	0.1383	0.2072	0.0957
	Post-10,000-year	0.0723	0.3288	0.7862	1.1312	1.6058	0.7634
	Seepage Fraction	*0.489*	*0.681*	*0.789*	*0.804*	*0.845*	*0.753*
50th ***p* = 0.1645**	Present-Day	0.0020	0.0146	0.0219	0.0235	0.0384	0.0203
	Monsoon	0.0022	0.0214	0.0459	0.0560	0.1033	0.0430
	Glacial-Transition	0.0052	0.0442	0.1421	0.2249	0.3569	0.1422
	Post-10,000-year	0.1262	0.6129	1.0992	1.3027	1.7298	1.0114
	Seepage Fraction	*0.504*	*0.715*	*0.800*	*0.798*	*0.828*	*0.765*
90th ***p* = 0.0596**	Present-Day	0.0084	0.0657	0.0974	0.0960	0.1441	0.0870
	Monsoon	0.0523	0.3686	0.5595	0.5942	0.7903	0.5066
	Glacial-Transition	0.0182	0.1826	0.3863	0.4695	0.6805	0.3525
	Post-10,000-year	0.2323	0.8628	1.2257	1.2925	1.6400	1.1227
	Seepage Fraction	*0.582*	*0.800*	*0.863*	*0.859*	*0.881*	*0.833*
TSPA Mean Results	Present-Day	0.0010	0.0080	0.0120	0.0128	0.0202	0.0111
	Monsoon	0.0045	0.0326	0.0516	0.0565	0.0815	0.0472
	Glacial-Transition	0.0038	0.0280	0.0750	0.1189	0.1979	0.0768
	Post-10,000-year	0.0985	0.3995	0.6366	0.7216	0.9597	0.5878
	Seepage Fraction	*0.467*	*0.648*	*0.720*	*0.705*	*0.753*	*0.687*

NOTE: TSPA seepage data extracted at 500-, 750-, 10,000-, and 1,000,000-year time steps for the present-day, monsoon, glacial-transition, and post-10,000-year climate states, respectively. The data was extracted from the TSPA Seismic Ground Motion Modeling Case for 1,000,000 years and is averaged over the epistemic uncertainties.

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations: SAR Section 2.3.2.4.1.2.4.5.5.
[b]The seepage values were extracted from the Seismic Ground Motion 1,000,000-year modeling case.
[c]Percolation subregions and quantile ranges SAR Section 2.4.2.3.2.1.2.

1.4 SUMMARY

The results presented in Tables 1 to 11 include the TSPA model percolation and seepage output for the nominal and seismic ground motion modeling cases and are consistent with the summary results presented in SAR Section 2.3.3 for the seepage model and SAR Sections 2.1 (Demonstration of Multiple Barriers) and 2.4 (Demonstration of Compliance with Postclosure Public Health and Environmental Standards). In addition, the TSPA model summary data is consistent with the input from the precipitation and infiltration model results, as documented in SAR Section 2.3.1, and with the site-scale unsaturated zone flow model results, as documented in SAR Section 2.3.2.

Table 11. Summary Values Spatially Averaged over the Repository Footprint

Infiltration Percentile[a]	Climate State	Precipitation (mm/yr)	Unsaturated Zone Flow Model Percolation at the base of PTn (mm/yr)	Ratio of Percolation to Precipitation (%)	MSTHM Percolation at base of PTn (m^3/yr per waste package)	Seepage (m^3/yr per waste package)		Ratio of Seepage to Percolation (%)	
						Nominal	Seismic	Nominal	Seismic
10th p = 0.6191	Present-Day	150.9	4.1	2.7	0.115	0.001	0.001	0.8	0.8
	Monsoon	216.2	7.8	3.6	0.219	0.005	0.006	2.4	2.5
	Glacial-Transition	284.4	12.2	4.3	0.341	0.016	0.020	4.8	5.9
	Post-10,000-year	—	21.58	—	0.603	0.042	0.241	7.0	40.0
30th p = 0.1568	Present-Day	168.2	10.2	6.1	0.287	0.008	0.008	2.8	2.8
	Monsoon	157.8	16.1	10.2	0.452	0.026	0.027	5.8	5.9
	Glacial-Transition	277.3	26.3	9.5	0.737	0.070	0.082	9.5	11.1
	Post-10,000-year	—	40.76	—	1.132	0.148	0.612	13.1	54.1
50th p = 0.1645	Present-Day	198.2	14.6	7.4	0.410	0.015	0.016	3.7	3.8
	Monsoon	252.1	19.5	7.7	0.548	0.037	0.037	6.7	6.7
	Glacial-Transition	233.6	36.2	15.5	1.015	0.109	0.123	10.7	12.1
	Post-10,000-year	—	52.07	—	1.452	0.195	0.804	13.4	55.3
90th p = 0.0596	Present-Day	222.7	34.1	15.3	0.956	0.072	0.074	7.5	7.8
	Monsoon	324.7	92.4	28.5	2.592	0.438	0.446	16.9	17.2
	Glacial-Transition	300.0	69.7	23.2	1.955	0.278	0.312	14.2	15.9
	Post-10,000-year	—	61.86	—	1.728	0.226	0.960	13.1	55.6
Weighted Mean Results	Present-Day	—	8.57	**TSPA Mean Results**	0.24	0.01	0.01	4.0	4.0
	Monsoon	—	16.07		0.45	0.04	0.04	9.0	9.0
	Glacial-Transition	—	21.79		0.61	0.06	0.06	10.0	10.0
	Post-10,000-year	—	32.00		0.89	0.1	0.43	11.0	49.0

Source: [a]GLUE probability weighting factors for the 10th, 30th, 50th, and 90th percentile infiltration realizations SAR Section 2.3.2.4.1.2.4.5.5.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

SNL (Sandia National Laboratories) 2007. *UZ Flow Models and Submodels*. MDL-NBS-HS-000006 REV 03 AD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080108.0003; DOC.20080114.0001; LLR.20080414.0007; LLR.20080414.0033; LLR.20080522.0086.

SNL 2008. *Total System Performance Assessment Model /Analysis for the License Application*. MDL-WIS-PA-000005 REV 00 AD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080312.0001; LLR.20080414.0037; LLR.20080507.0002; LLR.20080522.0113; DOC.20080724.0005.

RAI Volume 3, Chapter 2.2.1.3.5, First Set, Number 2, Supplemental:

> Tabulate data summarized in the four uncertainty maps of net infiltration (SNL, 2008) for each of the four climate states. The information should include net infiltration and spatial coordinates. This information is needed to evaluate compliance with 10 CFR 63.114(a)(2).

1. RESPONSE

As discussed in the May 26, 2009, clarification call with the NRC, in addition to providing the tabulated data requested in the RAI, a discussion of the methodology for developing the infiltration maps, including the selection and scaling processes used, is provided. This response provides (1) preliminary pre-10,000-year period net infiltration output data for the four uncertainty scenarios for the three climate states used in downstream models (namely, *UZ Flow Models and Submodels* (SNL 2007a) and *Calibrated Unsaturated Zone Properties* (SNL 2007b)) and (2) a list of net infiltration maps used for the post-10,000-year period. For the pre-10,000-year period, the response summarizes the selection method of the net infiltration maps corresponding to the four uncertainty scenarios. For the post-10,000-year period, net infiltration was derived from the log-uniform (13 to 64 mm/yr) distribution of deep percolation flux ranges specified in the proposed 10 CFR 63.342(c)(2).

Development of net infiltration values for the pre-10,000-year period is summarized in Section 1.1. For the post-10,000-year period, a different approach was used. The net infiltration values were derived to be consistent with the average percolation flux range through the repository footprint specified in the NRC proposed 10 CFR 63.342(c)(2). DOE performed a detailed comparison between the proposed 10 CFR Part 63 and the final 10 CFR Part 63 that became effective on April 13, 2009 (see response to RAI 3.2.2.1.2.1-5-001).

Net infiltration data sources used in the unsaturated zone flow model are documented in *UZ Flow Models and Submodels* (SNL 2007a, Table 6.2-6).

1.1 PRE-10,000-YEAR NET INFILTRATION CALCULATIONS

For each of the three future climates (i.e., present-day, monsoon, and glacial-transition) spanning the 10,000-year period, two Latin Hypercube Sample (LHS) replicates of net infiltration input data were generated. Each replicate consisted of 20 realizations of input parameter values, totaling 40 realizations per climate state. Each realization produced a different map of spatially-varying infiltration across the infiltration model domain. From the 40 maps prepared for each climate state, four maps were selected to represent the uncertainty in each of the climate states (SNL 2008, Section 6.5.7). To identify the four uncertainty maps of net infiltration, the mean weighted net infiltration over the entire infiltration model domain was calculated for each of the 40 realizations. For each climate state, the distribution of mean weighted net infiltration values was used to select the 10th, 30th, 50th and 90th percentile values. These four values were used to identify the maps that most closely matched the 10th, 30th, 50th, and 90th percentiles of the probability distribution. The selected replicates and realizations are shown in Table 1.

Net infiltration values for the three pre-10,000-year climate states corresponding to the selected replicates and realizations are provided in the electronic files included with this response. These files contain net infiltration data with spatial coordinates. The spatial coordinates correspond to Easting and Northing coordinates of each grid cell in Universal Transverse Mercator (UTM) NAD 27, Zone 11 (meters) (SNL 2008). File names are given in Table 1 and also in Section 5, where the files are mapped to the corresponding enclosure numbers.

For the pre-10,000-year period, the net infiltration data originated in two cycles. Initial preliminary net infiltration values used in downstream models were obtained from calculations from the Mass Accounting System for Soil Infiltration and Flow (MASSIF) infiltration model described in *Simulation of Net Infiltration for Present-Day and Potential Future Climates* (SNL 2008, Appendix L). Although the preliminary net infiltration data were subsequently replaced by the final product outputs (SNL 2008, Section 8[a]), the preliminary net infiltration values were qualified for use in downstream models based on additional analysis against the final values. This additional analysis considered a number of comparisons between the preliminary and final data, and evaluated the potential impacts on downstream models due to data differences. It was found that the differences were small relative to the uncertainty and not statistically significant so that there was no impact from using the preliminary set of output.

For the additional analysis, the present-day, monsoon and glacial-transition mean infiltration values were calculated for the infiltration modeling domain, unsaturated zone modeling domain, and repository footprint for the 10th, 30th, 50th, and 90th percentile maps. For the present-day, 10th percentile infiltration map, the mean infiltration over the repository footprint changed from 4.03 mm/yr (preliminary data) to 3.87 mm/yr (final data). Infiltration values decreased in most cases. The largest increase in mean infiltration over the repository footprint was for the monsoon climate map, 50th percentile, increasing from 19.43 to 28.81 mm/yr. Increased mean infiltration over the repository footprint increased for the following cases: present-day climate, 90th percentile map; monsoon climate, 30th and 50th percentile maps, and glacial-transition climate, 50th percentile map. In the total system performance assessment (TSPA) probability weighting factors of 62%, 16%, 16%, and 6% derived from the generalized likelihood uncertainty evaluation (GLUE) procedure are applied to the 10th, 30th, 50th, and 90th percentile maps, respectively. The analysis indicated these changes are insignificant.

The following conclusions were made based on the analysis:

- Differences in the infiltration rates obtained for the different climate conditions using the preliminary and final infiltration data are not statistically significant

- Differences between the mean infiltration rates over the repository footprint, based on preliminary and final infiltration data, are not statistically significant

- Differences between the preliminary and final mean infiltration rates are small compared to the uncertainty in infiltration rates.

1.2 POST-10,000-YEAR NET INFILTRATION CALCULATIONS

The post-10,000-year period net infiltration maps were derived using the average percolation flux ranges specified in the proposed 10 CFR 63.342(c)(2) (SAR Section 2.3.2.4.1.2.4.2). The post-10,000-year percolation results were based on the proposed rule log-uniform (13 to 64 mm/yr) distribution (SNL 2007a, Section 6.1.4) and not the truncated log-normal (10 to 100 mm/yr) distribution as revised in the final rule. The percolation fluxes specified in the proposed rule were taken to be equal to the average net infiltration at ground surface through the projection of the repository footprint based on unsaturated zone flow model results (SNL 2007a, Section 6.1.4). Applying unsaturated zone flow calibration process results to the 10th, 30th, 50th, and 90th percentile uncertainty maps for the three pre-10,000-year climate states resulted in adjusted uncertainty weights using the GLUE procedure for those maps of 62%, 16%, 16%, and 6%, respectively (SNL 2007a, Table 6.8-1). The midpoints of the cumulative distributions of the adjusted uncertainty ranges are 31%, 70%, 86%, and 97%. Applying these adjusted, cumulative probability values to the log-uniform percolation flux distribution specified in the NRC-proposed 10 CFR 63.342(c)(2) provides four target net infiltration rates averaged over the repository footprint: 21.29, 39.52, 51.05, and 61.03 mm/yr (SNL 2007a, Table 6.1-3).

The 12 infiltration maps generated for the present-day, monsoon, and glacial-transition climate states in the pre-10,000-year period are the bases for the spatial variability of net infiltration for the post-10,000-year period (SNL 2007a, Section 6.1.4). The average infiltration values through the projected repository footprint for each of the 12 infiltration maps are shown in Table 2. Four infiltration maps with suitable average infiltration rates were then selected as follows. The description below details what was actually done for TSPA and is slightly different from that described in SNL (2007a, Section 6.1.4). This difference would result in different infiltration maps, but in either event, the average net infiltration rate over the repository footprint (Table 2), would satisfy 10 CFR 63.342(c)(2).

The pre-10,000-year maps were selected as follows:

- The map with the highest average infiltration rate through the repository footprint was selected for developing the post-10,000-year 90th percentile uncertainty map.
- The map with the second highest average infiltration rate through the repository footprint was selected for developing the post-10,000-year 50th percentile map.
- The map with the third highest average infiltration rate through the repository footprint was selected for developing the post-10,000-year 30th percentile map.
- The map with the fourth highest average infiltration rate through the repository footprint was selected for developing the post-10,000-year 10th percentile map.

The four selected net infiltration maps were then scaled so the average infiltration through the projected repository footprint would closely match the target values. The selected maps are identified and the scaling factors are provided in Table 3.

Table 1. Net Infiltration Scenario Selected Replicates and Realizations

Scenario (Percentile)	Replicate Number	Realization Number	File Name
Present-Day Climate State			
10th	2	18	*PD_R2_V18_Infiltration.txt*
30th	1	13	*PD_R1_V13_Infiltration.txt*
50th	1	18	*PD_R1_V18_Infiltration.txt*
90th	2	17	*PD_R2_V17_Infiltration.txt*
Monsoon Climate State			
10th	1	19	*MO_R1_V19_Infiltration.txt*
30th	1	17	*MO_R1_V17_Infiltration.txt*
50th	1	6	*MO_R1_V06_Infiltration.txt*
90th	2	15	*MO_R2_V15_Infiltration.txt*
Glacial-Transition Climate State			
10th	1	1	*GT_R1_V01_Infiltration.txt*
30th	1	2	*GT_R1_V02_Infiltration.txt*
50th	2	16	*GT_R2_V16_Infiltration.txt*
90th	1	5	*GT_R1_V05_Infiltration.txt*

Table 2. Calculated Average Net Infiltration Rate over the Repository Footprint for the Pre-10,000-Year Period

Net Infiltration Map Scenario (Percentile)	Unsaturated Zone Flow Model Upper Boundary Average Net Infiltration Rate over Repository Footprint (mm/yr)
Present-Day 10th	4.0
Present-Day 30th	10.1
Present-Day 50th	14.5
Present-Day 90th	33.8
Monsoon 10th	7.8
Monsoon 30th	16.0
Monsoon 50th	19.4
Monsoon 90th	91.8
Glacial-Transition 10th	11.9
Glacial-Transition 30th	25.9
Glacial-Transition 50th	35.5
Glacial-Transition 90th	68.9

Source: Extracted from unsaturated zone flow model results for the average upper boundary net infiltration over the repository footprint (supplemental response to RAI 3.2.2.1.3.6-005).

Table 3. Selected Net Infiltration Maps for the Post-10,000-Year Period

Post-10,000-Year Map (Percentile)	Target Average Net Infiltration Rate over Repository Footprint (mm/yr)[a]	Pre-10,000-Year Selected Match[a]	Average Net Infiltration Rate over Repository Footprint (Table 2) (mm/yr)	Scaling Factor
10th	21.29	Present-Day 90th	33.8	0.63
30th	39.52	Glacial-Transition 50th	35.5	1.12
50th	51.05	Glacial-Transition 90th	68.9	0.74
90th	61.03	Monsoon 90th	91.8	0.67

Source: [a]SNL 2007a, Table 6.1-3.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

SNL (Sandia National Laboratories) 2007a. *UZ Flow Models and Submodels.* MDL-NBS-HS-000006 REV 03 AD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080108.0003.

SNL 2007b. *Calibrated Unsaturated Zone Properties.* ANL-NBS-HS-000058 REV 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070530.0013.

SNL 2008. *Simulation of Net Infiltration for Present-Day and Potential Future Climates.* MDL-NBS-HS-000023 REV 01 AD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080201.0002.

5. LIST OF ATTACHMENTS

Electronic files containing net infiltration data along with spatial coordinates are provided as the following enclosures to the transmittal letter for this RAI response:[a]

Enclosure Number	File Name
Enclosure 9	PD_R2_V18_Infiltration.txt
Enclosure 10	PD_R1_V13_Infiltration.txt
Enclosure 11	PD_R1_V18_Infiltration.txt
Enclosure 12	PD_R2_V17_Infiltration.txt
Enclosure 13	MO_R1_V19_Infiltration.txt
Enclosure 14	MO_R1_V17_Infiltration.txt
Enclosure 15	MO_R1_V06_Infiltration.txt
Enclosure 16	MO_R2_V15_Infiltration.txt
Enclosure 17	GT_R1_V01_Infiltration.txt
Enclosure 18	GT_R1_V02_Infiltration.txt
Enclosure 19	GT_R2_V16_Infiltration.txt
Enclosure 20	GT_R1_V05_Infiltration.txt

NOTE: [a]Already provided as enclosures 9 through 20 to letter from Williams to Sulima dated 06/24/2009. “Yucca Mountain – Request for Additional Information - Volume 3 – Postclosure Chapter 2.2.1.3.5, 1st Set – Climate and Infiltration – (Department of Energy’s Safety Analysis Report Section 2.3.1).”